Formation of low-resistance, thermally stable, and transparent Pt-based ohmic contacts to surface-treated *p*-GaN

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[1] Introduction

Due to the successful development of GaN-based devices, such as blue light emitting diodes and laser diodes,[1,2] the fabrication of high quality ohmic contacts which have low resistance, thermal stability, and high transparency, is of great technological importance. In fact, the high contact resistance of *p*-GaN is one of the major obstacles to the realisation of long-lifetime CW operation of the GaN-based optical devices. It is, therefore, essential to develop high quality ohmic contacts on *p*-GaN to enhance device performance. In this work, we report on low-resistance, thermally stable, and high-transparency Pt-based ohmic contacts on *p*-GaN. In addition, the ohmic formation mechanisms for the Pt-based contacts are discussed.

[2] Experiment

Metalorganic chemical vapor deposition was used to grow a 1-μm-thick *p*-GaN:Mg (N_a = 2~3x10^{17} cm^{-3}) on a 2-μm-thick unintentionally doped GaN/(0001) sapphire substrate. The GaN layers were ultrasonically degreased with RCA cleaning for 5 min. Prior to the fabrication of TLM patterns, the samples were ultrasonically treated with a boiling buffered oxide etch (BOE) for 20 min. TLM patterns were defined by a photolithograhphic technique. The patterned samples were then treated in BOE for 30 s. The Pt (20 nm) and Pt/Ru (20 nm/50 nm) films were deposited by electron beam evaporation. The contacts were rapid-thermal-annealed in N_2 ambient. Current-voltage-temperature (I-V-T) relations were measured using parameter analyzer (HP 4155A). Glancing x-ray diffraction (GXRD), Auger electron spectroscopy (AES), and x-ray photoelectron spectroscopy (XPS) were used to study the interfacial reactions between metals and GaN. Atomic force microscope (AFM) and scanning electron spectroscope (SEM) were used to characterise the surface morphology of the contacts.

[3] Results and Discussion

The I-V characteristics of the Pt and Pt/Ru contacts on surface-treated *p*-GaN are shown in Fig. 1. The as-deposited Pt and Pt/Ru contacts show near-linear behavior. It is, however, shown that the I-V characteristics of the Pt and Pt/Ru contacts are improved upon annealing at 600 °C, leading to linear behavior. Specific contact resistances were determined from plots of the measured resistances versus the spacings between the TLM pads. The least square method was used to fit a straight line to the experimental data. The contact resistance was measured to be $7.1(\pm1.2)\times10^{-4}$ and $6.2(\pm1.6)\times10^{-4}$ Ωcm^2 for the as-deposited Pt and Pt/Ru contacts, respectively. It is shown that annealing of the contacts at 600 °C results in the improvement in contact resistance, namely, it was $4.8(\pm1.8)\times10^{-4}$ and $2.0(\pm2.0)\times10^{-6}$ Ωcm^2 for the Pt and Pt/Ru contacts, respectively. It is noteworthy that the annealed Pt/Ru contacts resulted in a dramatic reduction (by two orders of magnitude) in the specific contact resistance, compared to those of the as-deposited Pt/Ru and annealed Pt contacts. The low specific contact resistance observed in the as-deposited Pt and Pt/Ru samples can be attributed to the combined effects of the high work function of Pt in contact with *p*-GaN, the effective removal of native oxide on the GaN surface, and the reduced surface barrier height through the shift of surface Fermi level toward the valence band edge due to the surface treatment.[3-7] The further improvement in the contact resistance of the 600 °C Pt/Ru contact may be attributed to additional factors, such as the formation of interfacial reaction products and an increase in the contact area between the metal films and the GaN (due to the interfacial reactions).[8,9] It is noted that unlike the Pt/Ru contacts, the annealed Pt contact shows similar contact resistance to the as-deposited one. This may be associated with the formation of Pt-oxide. This will be further discussed using the XPS and AES results.

Figure 2 shows light-transmittance obtained form the Pt and Pt/Ru contacts as a function of annealing temperature. It is shown that the light-transmittance is gradually improved with increasing annealing temperature. It is clear that the light-transmittance of the Pt contacts is lower than that of the Pt/Ru contacts. This could be related to the stable interface, the alignment of the metal grains, and the role of the Ru layer.[10] Detailed ohmic and electronic transport mechanisms for the Pt and Pt/Ru contacts will be described and discussed using the XPS, I-V-T, AES, GXRD and transmission electron microscope (TEM) data.

[4] Conclusion

We report on the formation of low-resistance, thermally stable, and highly transparent Pt and Pt/Ru ohmic contacts on the surface-treated *p*-GaN. The I-V-T and light-transmittance measurements showed that the electrical, optical, and thermal properties of the Pt-based contacts were improved with increasing annealing temperature. The AES, GXRD, and XPS results showed that the formation of high-quality Pt-based contacts could be explained in terms of a change of the surface electronic properties due to the surface-treatment and interfacial/surface reactions.

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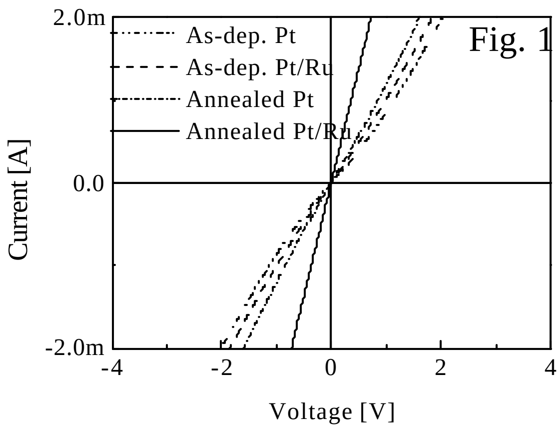

Figure 1. The I-V characteristics of the as-deposited and annealed Pt and Pt/Ru contacts.

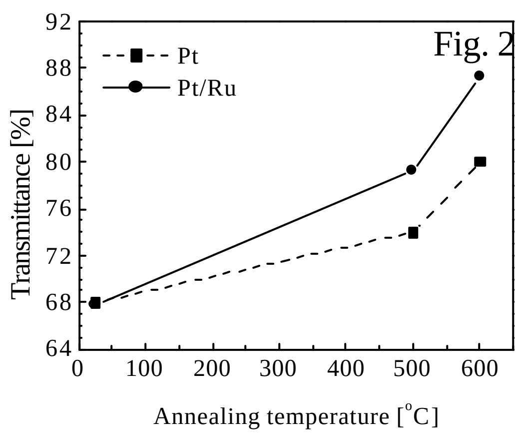

Figure 2. The light-transmittance of the Pt and Pt/Ru contacts as a function of annealing temperature.